5. SUMMARY OF FORECAST VERIFICATION

5.1 ANNUAL FORECAST VERIFICATION

Verification of warning positions and intensities at initial, 24-, 48- and 72-hour forecast periods was made against the final best track. The (scalar) track forecast, along-track and cross-track errors (illustrated in Figure 5-1) were calculated for each verifying JTWC forecast. These data, in addition to a detailed summary for each tropical cyclone, is included as Chapter 6 (formerly Annex A). This section summarizes verification data for 1992 and contrasts it with annual verification statistics from previous years.

5.1.1 NORTH WEST PACIFIC OCEAN — The frequency distributions of errors for initial warning positions and 12,- 24-, 36-, 48- and 72-hour forecasts are presented in Figures 5-2a through 5-2f, respectively. Table 5-1 includes mean track, along-track and cross-track errors for 1978-1992. Figure 5-3 shows mean track errors and a 5-year moving average of track errors at 24-, 48- and 72-hours for the past 23 years. Table 5-2 lists annual mean track errors from 1959, when the JTWC was founded, until the present. Figure 5-4 illustrates JTWC intensity forecast errors at 24-, 48- and 72-hours for the past 22 years.

5.1.2 NORTH INDIAN OCEAN — The frequency distributions of errors for warning positions and 12-, 24-, 36-, 48- and 72-hour forecasts are presented in Figures 5-5a through 5-5f, respectively. Table 5-3 includes mean track, along-track and cross-track errors for 1978-1992. Figure 5-6 shows mean track errors and a 5-year moving average of track errors at 24-, 48- and 72-hours for the 21 years that the JTWC has issued warnings in the region.

5.1.3 SOUTH PACIFIC AND SOUTH INDIAN OCEANS — The frequency distributions of errors for warning positions and 24- and 48-hour forecasts are presented in Figures 5-7A through 5-7C, respectively. Table 5-4 includes mean track, along-track and cross-track errors for 1981-1992. Figures 5-8 shows mean track errors and a 5-year moving average of track errors at 24- and 48-hours for the 12 years that the JTWC has issued warnings in the region.

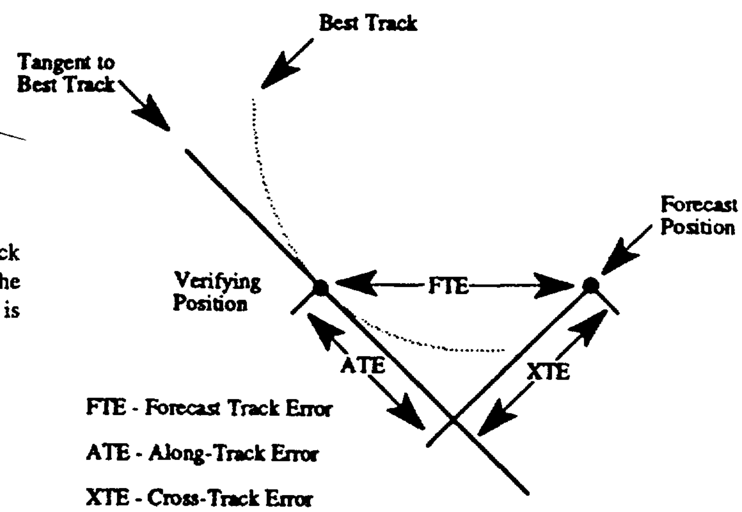


Figure 5-1. Definition of cross-track error (XTE), along-track error (ATE) and forecast track error (FTE). In this example, the XTE is positive (to the right of the best track) and the ATE is negative (behind or slower than the best track).

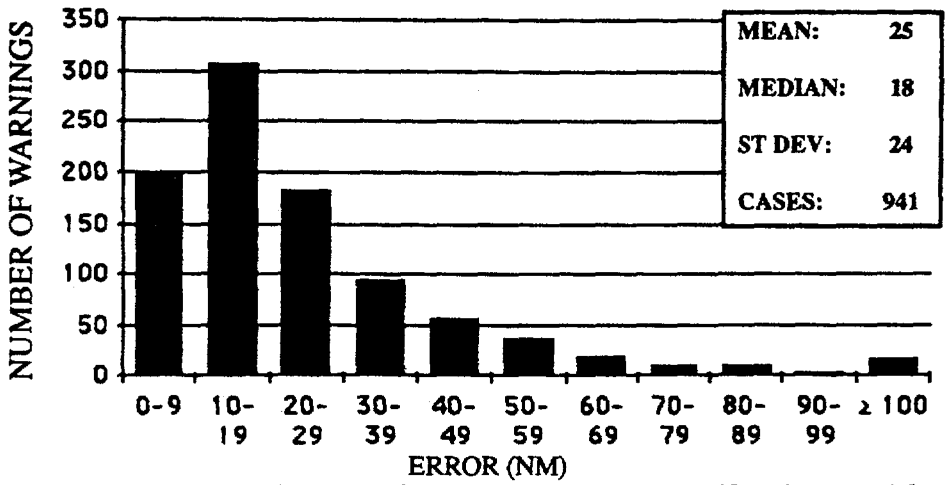


Figure 5-2a. Frequency distribution of initial warning position errors (10 nm increments) for the western North Pacific Ocean in 1992. The largest error, 249 nm, occurred on Typhoon Ward (22W).

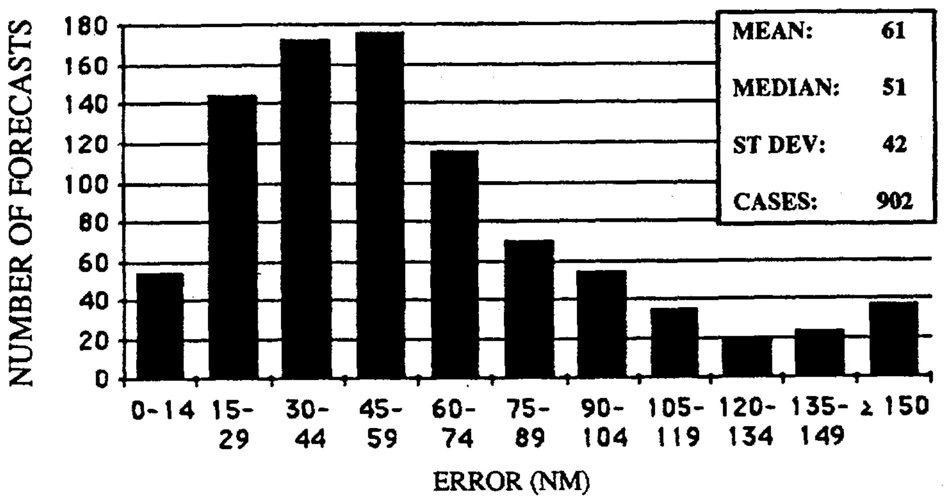


Figure 5-2b. Frequency distribution of 12-hour forecast errors (15 nm increments) for the western North Pacific Ocean in 1992. The largest error, 307 nm, occurred on Typhoon Ward (22W).

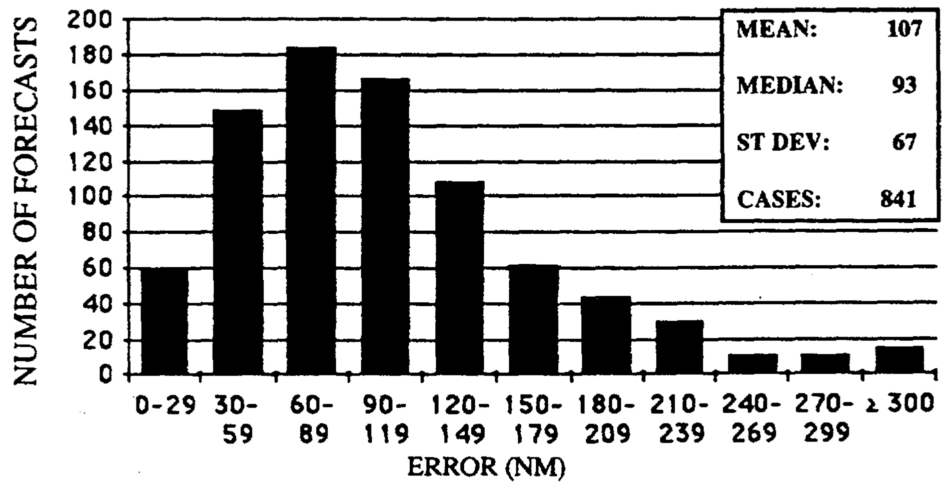


Figure 5-2c. Frequency distribution of 24-hour forecast errors (30 nm increments) for the western North Pacific Ocean in 1992. The largest error, 442 nm, occurred on Typhoon Hunt (32W).

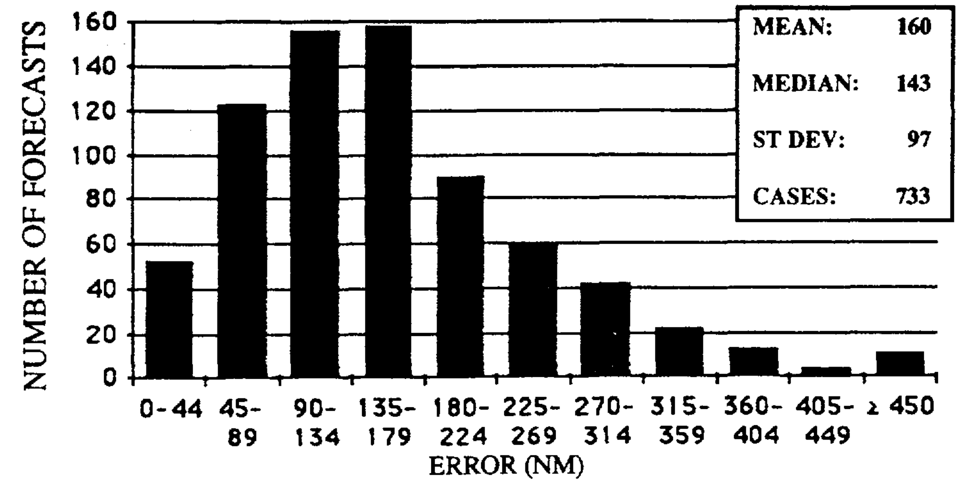


Figure 5-2d. Frequency distribution of 36-hour forecast errors (45 nm increments) for the western North Pacific Ocean in 1992. The largest error, 707 nm, occurred on Typhoon Hunt (32W).

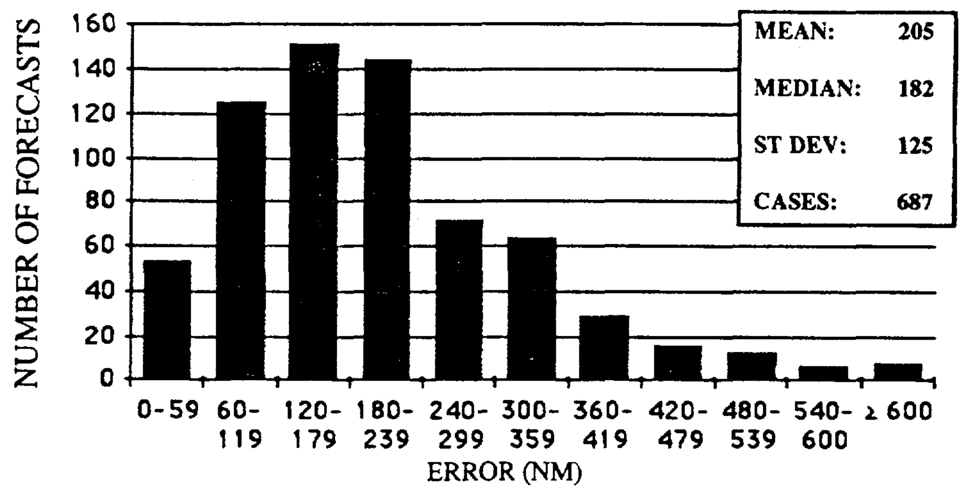


Figure 5-2e. Frequency distribution of 48 hour forecast errors (60 nm increments) for the western North Pacific Ocean in 1992. The largest error, 714 nm, occurred on Typhoon Colleen (26W).

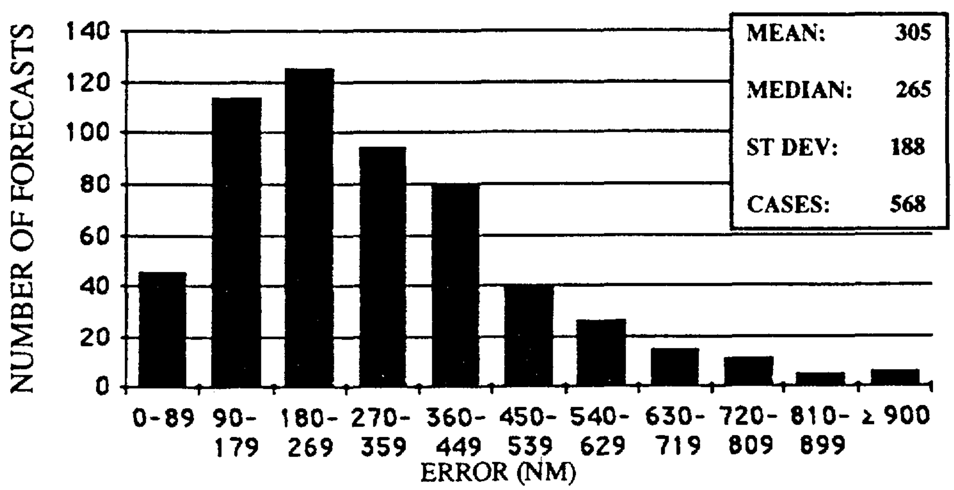


Figure 5-2f. Frequency distribution of 72-hour forecast errors (90 nm increments) for the western North Pacific Ocean in 1992. The largest error, 1014 nm, occurred on Typhoon Colleen (26W).

TABLE 5-1. INITIAL WARNING POSITION AND FORECAST ERRORS (NM) FOR THE WESTERN NORTH PACIFIC 1978-1992.

YEAR	NUMBER OF WARNINGS	INITIAL POSITION	24-HOUR NUMBER OF FORECASTS	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	48-HOUR NUMBER OF FORECASTS	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS	72-HOUR NUMBER OF FORECASTS	72-HOUR TRACK	72-HOUR ALONG	72-HOUR CROSS
1978	696	21	556	126	87	71	420	274	194	151	295	411	296	218
1979	695	25	589	125	81	76	469	227	146	138	366	316	214	182
1980	590	28	491	127	86	76	369	244	165	147	267	391	266	230
1981	584	25	466	124	80	77	348	221	146	131	246	334	206	219
1982	786	19	666	113	74	70	532	238	162	142	425	342	223	211
1983	445	16	342	117	76	73	253	260	169	164	184	407	259	263
1984	611	22	492	117	84	64	378	232	163	131	286	363	238	216
1985	592	18	477	117	80	68	336	231	153	138	241	367	230	227
1986	743	21	645	126	85	70	535	261	183	151	412	394	276	227
1987	657	18	563	107	71	64	465	204	134	127	389	303	198	186
1988	465	23	373	114	85	58	262	216	170	103	183	315	244	159
1989	710	20	625	120	83	69	481	231	162	127	363	350	265	177
1990	794	21	658	120	81	70	404	237	162	138	305	355	242	211
1991	835	22	733	96	69	53	599	185	137	97	484	287	229	146
1992	941	25	841	107	77	59	687	205	143	116	568	305	210	172
AVERAGE 78-92:	676	22	568	116	79	67	436	229	158	131	334	343	237	198

NOTE: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after the fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

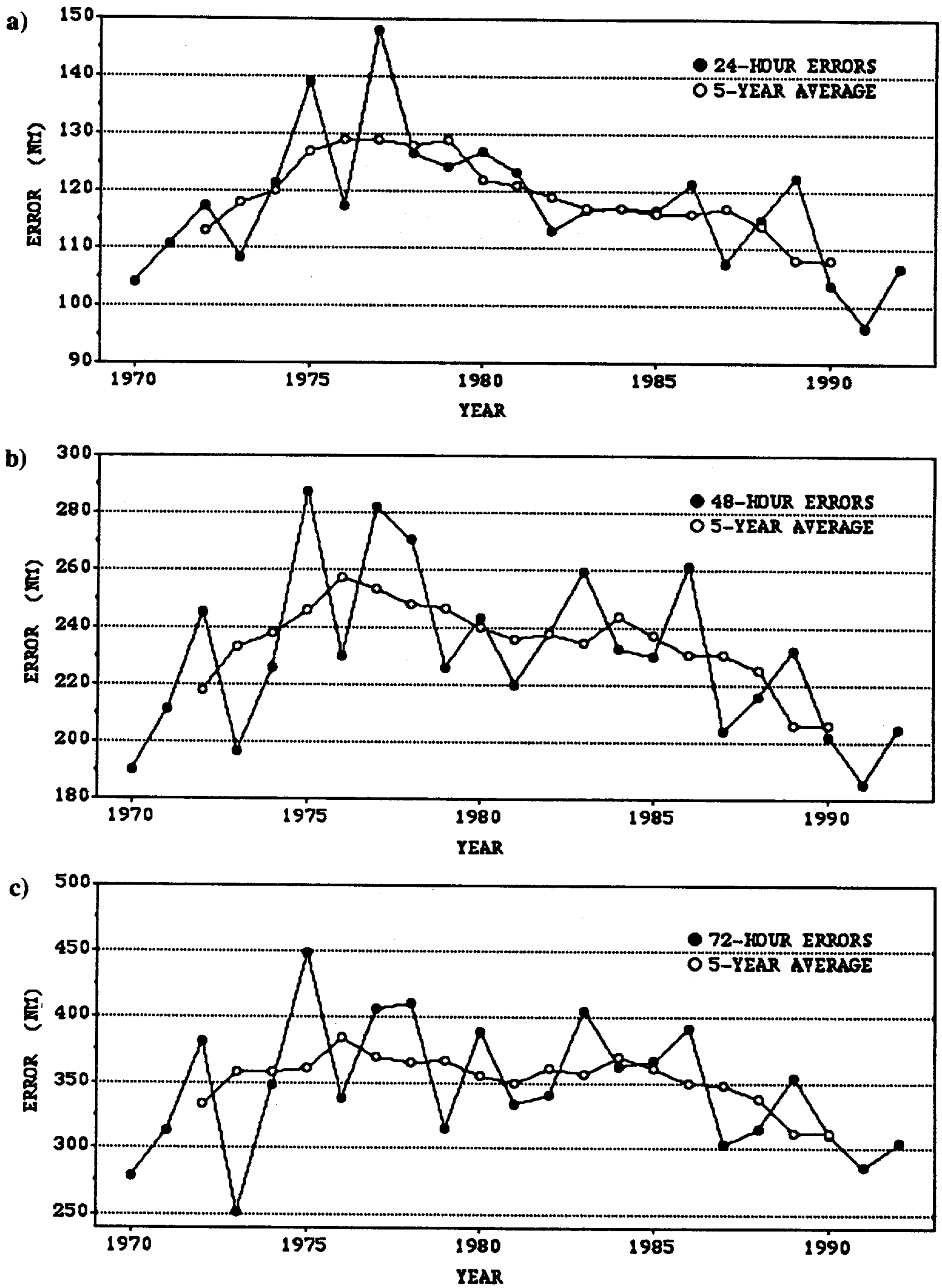


Figure 5-3. Mean track forecast error (nm) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours for the western North Pacific Ocean in 1992.

TABLE 5-2 **MEAN FORECAST ERRORS (NM) WESTERN NORTH PACIFIC**

	24-HOUR		48-HOUR		72-HOUR	
YEAR	ALL /	TYPHOONS*	ALL /	TYPHOONS*	ALL /	TYPHOONS*
1959		117**		267**		
1960		177**		354**		
1961		136		274		
1962		144		287		476
1963		127		246		374
1964		133		284		429
1965		151		303		418
1966		136		280		432
1967		125		276		414
1968		105		229		337
1969		111		237		349
1970	104	98	190	181	279	272
1971	111	99	212	203	317	308
1972	117	116	245	245	381	382
1973	108	102	197	193	253	245
1974	120	114	226	218	348	357
1975	138	129	288	279	450	442
1976	117	117	230	232	338	336
1977	148	140	283	266	407	390
1978	127	120	271	241	410	459
1979	124	113	226	219	316	319
1980	126	116	243	221	389	362
1981	123	117	220	215	334	342
1982	113	114	237	229	341	337
1983	117	110	259	247	405	384
1984	117	110	233	228	363	361
1985	117	112	231	228	367	355
1986	121	117	261	261	394	403
1987	107	101	204	211	303	318
1988	114	107	216	222	315	327
1989	120	107	231	214	350	325
1990	103	98	203	191	310	299
1991	96	93	185	187	286	298
1992	107	97	205	194	305	295

* Forecasts were verified when the tropical cyclone intensities were at least 35 kt (18 m/sec).

** Forecast positions north of 35° north latitude were not verified.

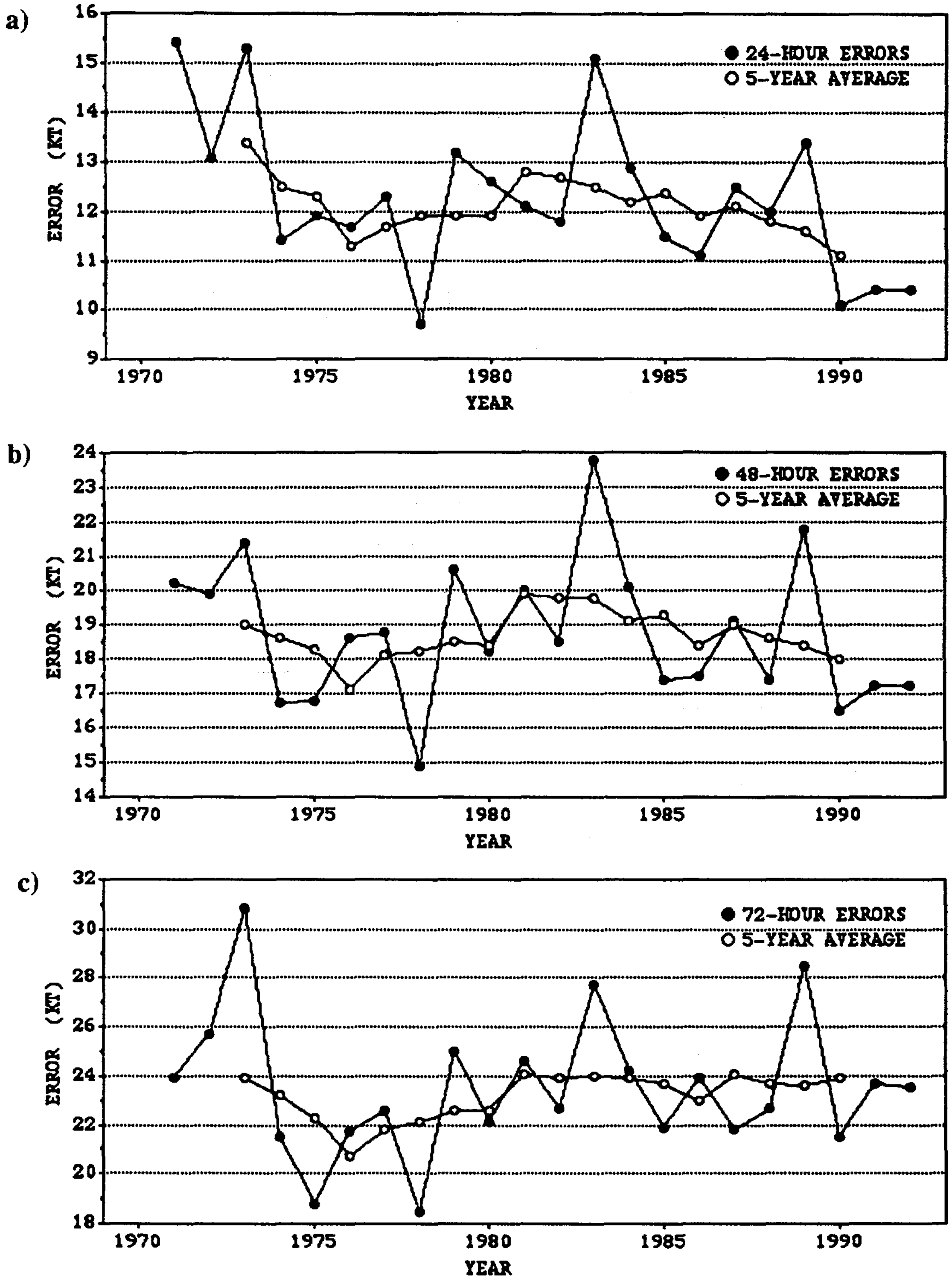


Figure 5-4. Mean intensity forecast errors (kt) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours for the western North Pacific Ocean in 1992.

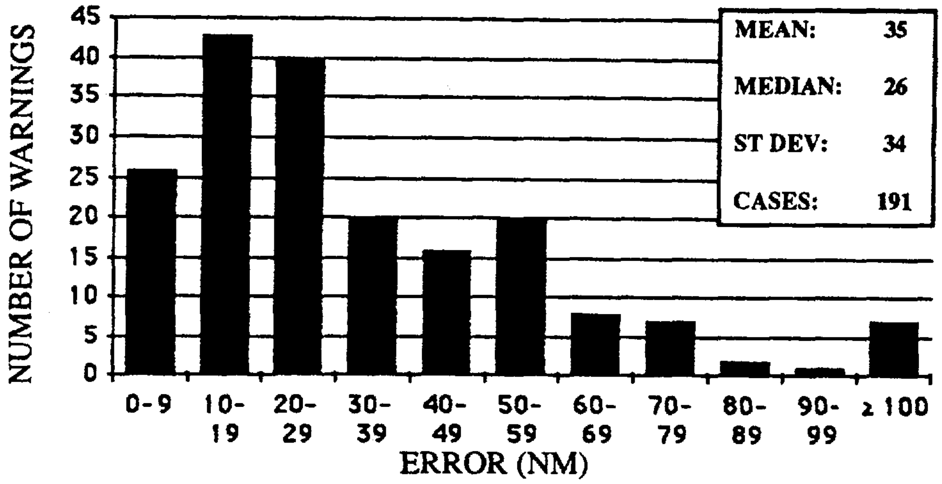


Figure 5-5a. Frequency distribution of initial warning position errors (10 nm increments) for the North Indian Ocean in 1992. The largest error, 306 nm, was on TC02A.

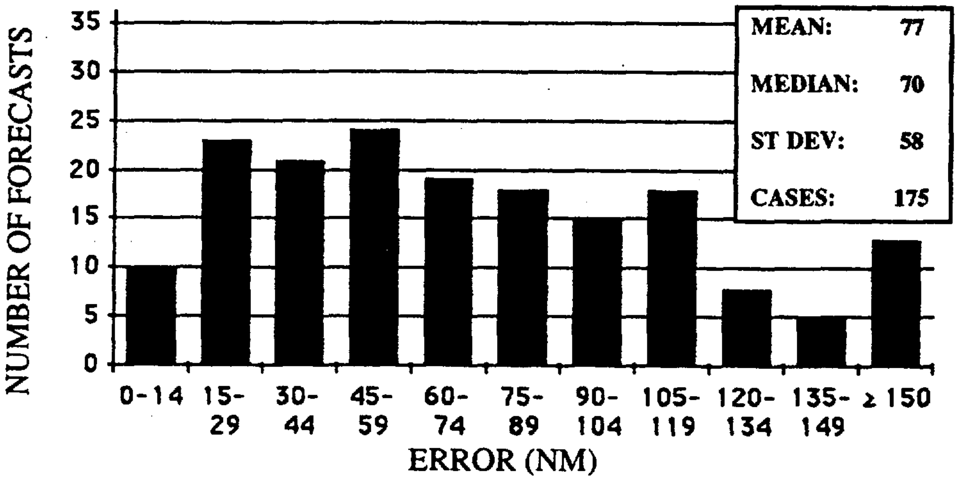


Figure 5-5b. Frequency distribution of 12-hour forecast errors (15 nm increments) for the North Indian Ocean in 1992. The largest error, 460 nm, was on TC02A.

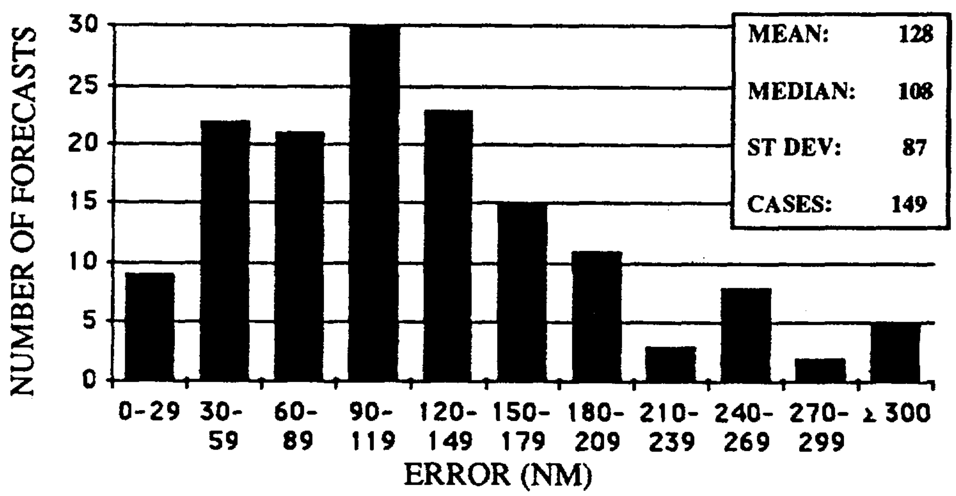


Figure 5-5c. Frequency distribution of 24-hour forecast errors (30 nm increments) for the North Indian Ocean in 1992. The largest error, 592 nm, was on TC02A.

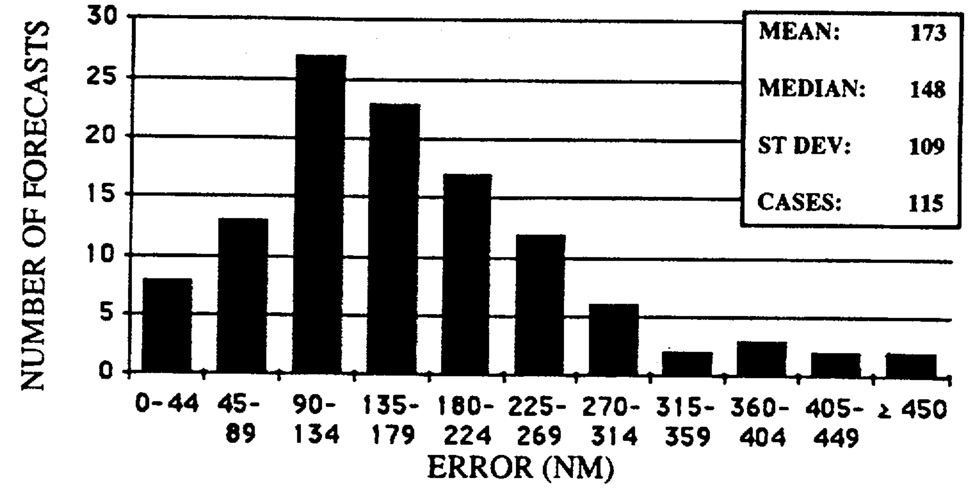


Figure 5-5d. Frequency distribution of 36-hour forecast errors (45 nm increments) for the North Indian Ocean in 1992. The largest error, 683 nm, was on TC02A.

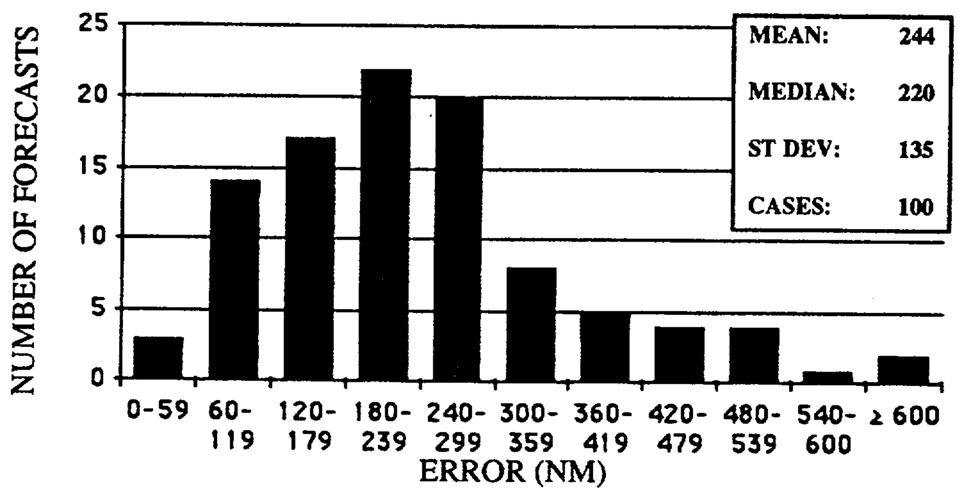


Figure 5-5e. Frequency distribution of 48-hour forecast errors (60 nm increments) for the North Indian Ocean in 1992. The largest error, 733 nm, was on TC02A.

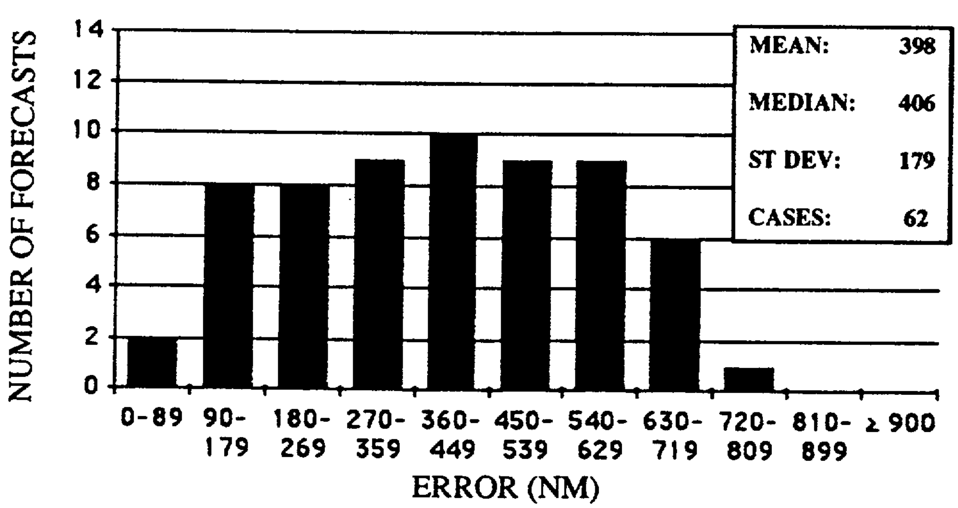


Figure 5-5f. Frequency distribution of 72-hour forecast errors (90 nm increments) for the North Indian Ocean in 1992. The largest error, 723 nm, was on TC02A.

TABLE 5-3. JTWC ANNUAL INITIAL POSITION AND FORECAST POSITION ERRORS (NM) 1978-1992 FOR THE NORTH INDIAN OCEAN

YEAR	NUMBER OF WARNINGS	INITIAL POSITION	24-HOUR NUMBER OF FORECASTS	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	48-HOUR NUMBER OF FORECASTS	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS	72-HOUR NUMBER OF FORECASTS	72-HOUR TRACK	72-HOUR ALONG	72-HOUR CROSS
1978	32	43	28	133	90	82	19	202	147	109	N/A			
1979	93	46	63	151	96	95	17	278	193	161	17	437	251	320
1980	14	41	7	115	81	71	38	93	25	88	1	167	97	137
1981	41	28	29	109	76	63	2	176	120	109	5	197	150	111
1982	55	35	37	138	110	68	17	368	292	209	7	762	653	332
1983	18	38	7	117	90	50	18	153	137	53	0			
1984	67	33	42	154	124	67	20	274	217	139	16	388	339	121
1985	53	31	30	122	102	53	8	242	119	194	0			
1986	28	52	16	134	118	53	7	168	131	80	5	269	189	180
1987	83	42	54	144	91	100	25	205	125	140	21	305	219	188
1988	44	34	30	120	89	63	18	219	112	176	12	409	227	303
1989	44	19	33	88	62	50	17	146	94	86	12	216	164	111
1990	46	31	36	101	85	43	24	146	117	67	17	185	130	104
1991	56	38	43	129	107	54	27	235	200	89	14	450	356	178
1992	191	35	149	128	73	86	100	244	141	166	62	398	276	218
AVERAGE 78-92:	58	36	40	129	90	73	23	221	147	134	13	368	263	201

NOTE: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after the fact to extend the data base. See Figure 5-1 for the definitions of cross-track and along-track errors.

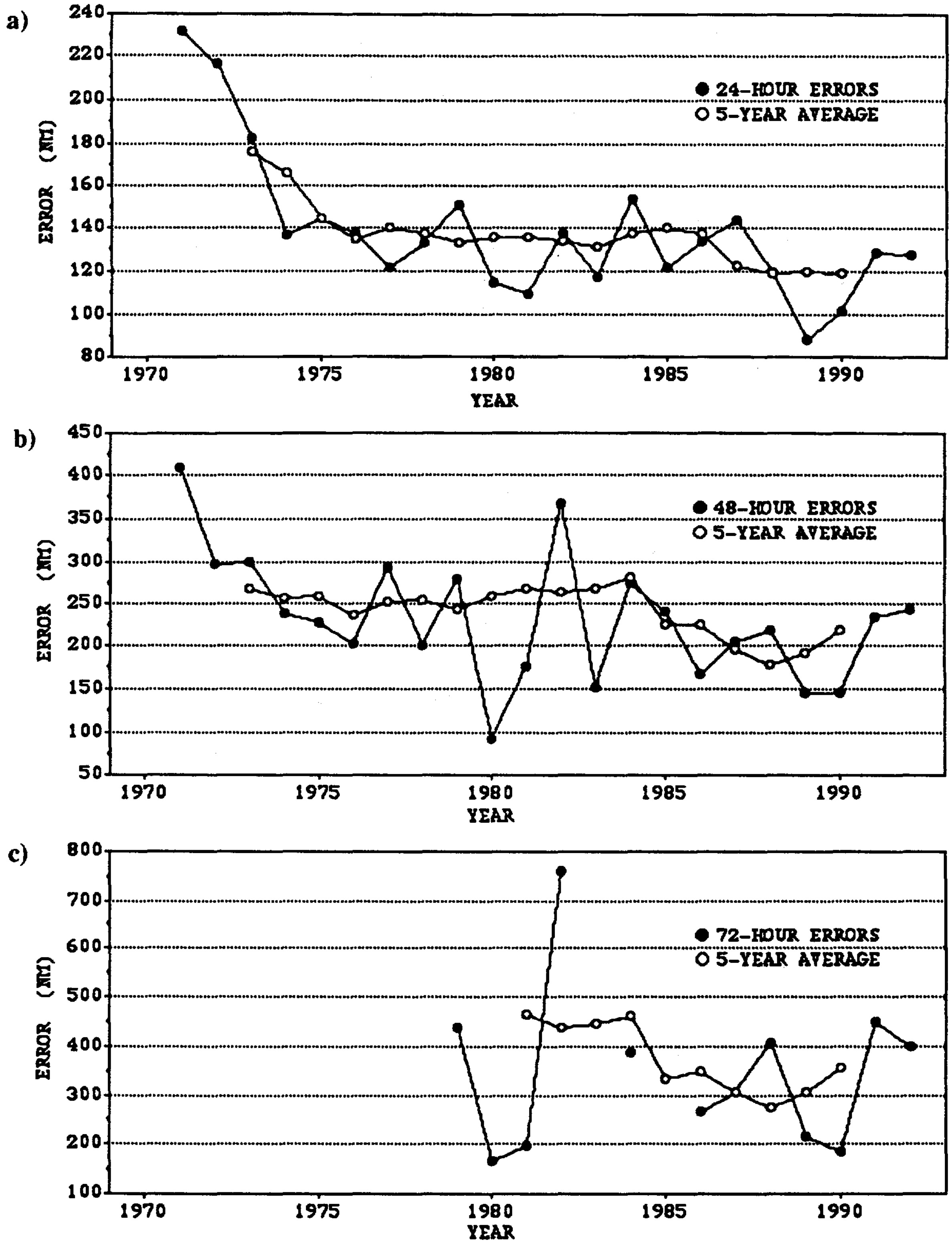


Figure 5-6. Mean track errors (nm) and 5-year running mean for a) 24 hours, b) 48 hours and c) 72 hours in the North Indian Ocean. Note: no 72-hour forecasts verified prior to 1979, in 1983 and 1985.

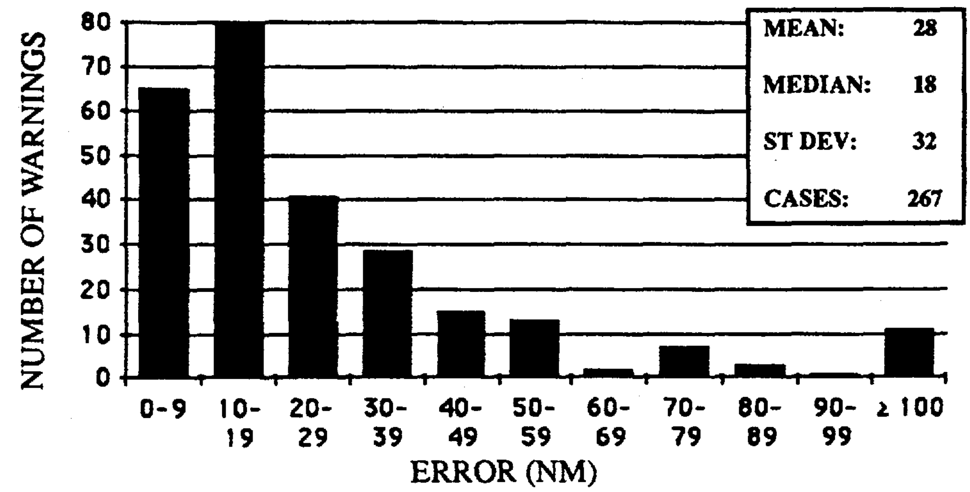


Figure 5-7a. Frequency distribution of initial warning position errors (10 nm increments) for the South Pacific and South Indian Oceans. The largest error, 297 nm, occurred on Tropical Cyclone 15P (Celesta).

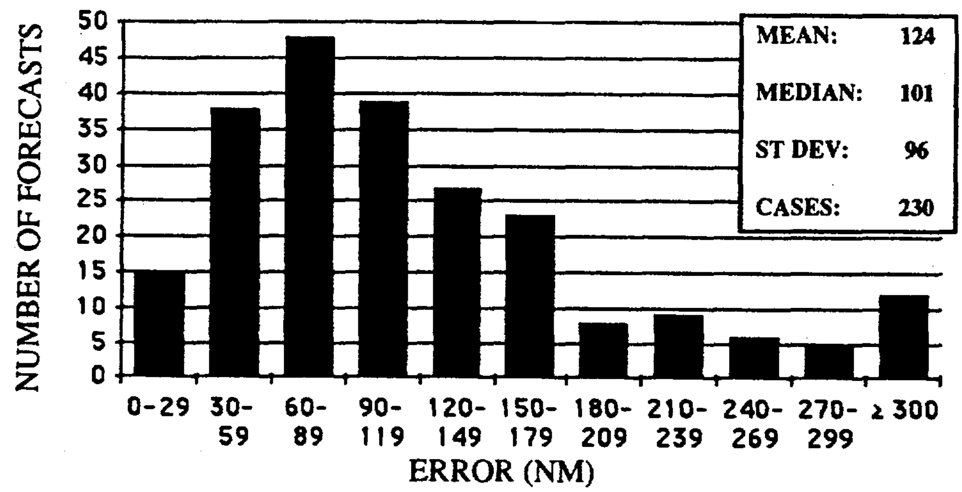


Figure 5-7b. Frequency distribution of 24-hour forecast errors (30 nm increments) for the South Pacific and South Indian Oceans. The largest error, 620 nm, occurred on Tropical Cyclone 15P (Celesta).

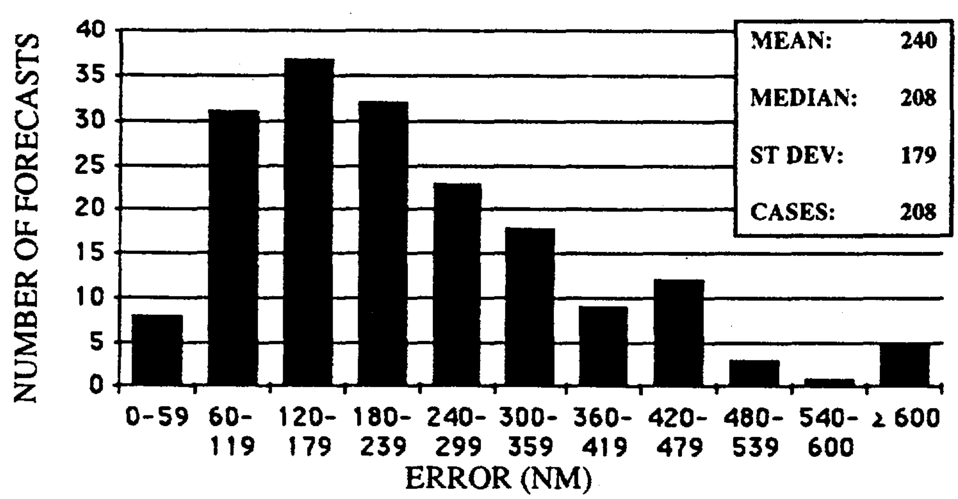


Figure 5-7c. Frequency distribution of 48-hour forecast errors (60 nm increments) for the South Pacific and South Indian Oceans. The largest error, 1281 nm, occurred on Tropical Cyclone 03P (Tia).

TABLE 5-4. JTWC ANNUAL INITIAL POSITION AND FORECAST POSITION ERRORS (NM) 1981-1992 FOR THE SOUTHERN HEMISPHERE

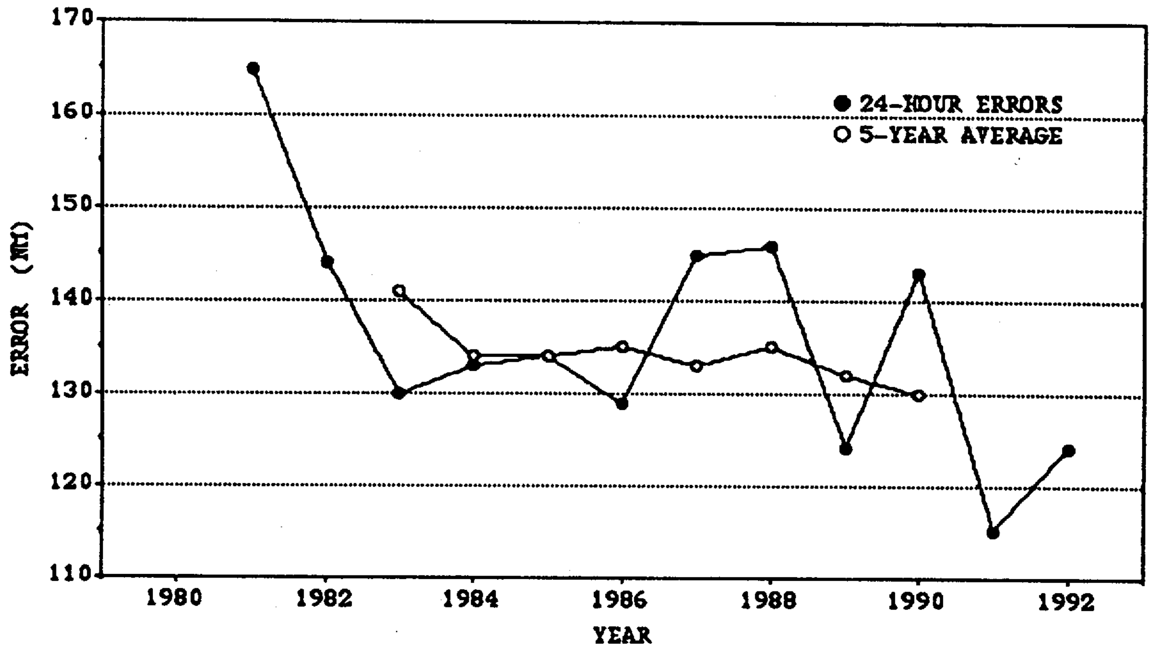
YEAR	NUMBER OF WARNINGS	INITIAL POSITION	NUMBER OF FORECASTS (24-HOUR)	24-HOUR TRACK	24-HOUR ALONG	24-HOUR CROSS	NUMBER OF FORECASTS (48-HOUR)	48-HOUR TRACK	48-HOUR ALONG	48-HOUR CROSS
1981	226	48	190	165	103	106	140	315	204	201
1982	275	38	238	144	98	86	176	274	188	164
1983*	191	35	163	130	88	77	126	241	158	145
1984	301	36	252	133	90	79	191	231	159	134
1985*	306	36	257	134	92	79	193	236	169	132
1986*	279	40	227	129	86	77	171	262	169	164
1987*	189	46	138	145	94	90	101	280	153	138
1988*	204	34	99	146	98	83	48	290	246	144
1989*	287	31	242	124	84	73	186	240	166	136
1990*	272	27	228	143	105	74	177	263	178	152
1991*	264	24	231	115	75	69	185	220	152	129
1992*	267	28	230	124	91	64	208	240	177	129
AVERAGE 81-92:	255	35	208	135	91	79	156	246	168	141

NOTE: Cross-track and along-track errors were adopted by the JTWC in 1986. Right-angle errors (used prior to 1986) were recomputed as cross-track and along-track errors after the fact to extend the data base.

See Figure 5-1 for the definitions of cross-track and along-track errors.

* These statistics are for JTWC forecasts only. NWOC statistics are not included.

a)



b)

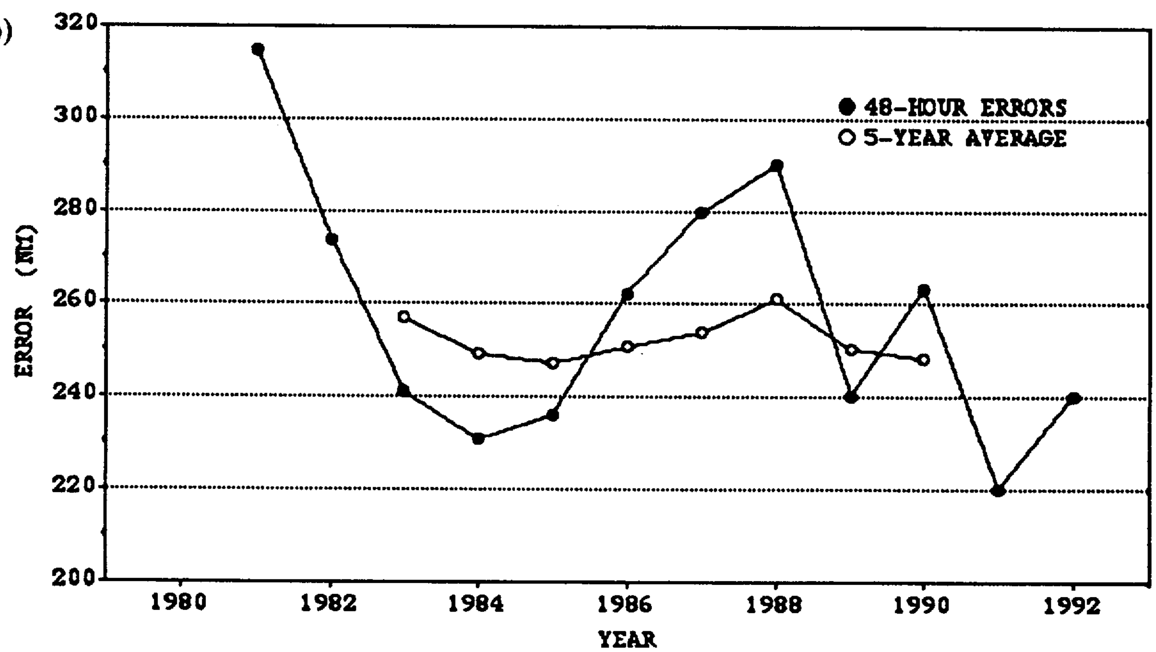


Figure 5-8. Mean track forecast errors (nm) and 5-year running mean for a) 24 hours and b) 48 hours for the South Pacific and South Indian Oceans.

5.2 COMPARISON OF OBJECTIVE TECHNIQUES

JTWC uses a variety of objective techniques for guidance in the warning development process. Multiple techniques are required, because each technique has particular strengths and weaknesses which vary by basin, numerical model initialization, time of year, synoptic situation and forecast period. The accuracy of objective aid forecasts depends on both the specified position and the past motion of the tropical cyclone as determined by the working best track. JTWC initializes its objective techniques using the extrapolated warning position.

An initiative is presently underway to convert most of the objective techniques that currently run on mainframe computers at FNOC to desktop computer versions that run on ATCF workstations. These will eventually replace the FNOC-generated techniques. Three of these new aids have been received and are under evaluation.

Unless stated otherwise, all the objective techniques discussed below run in all basins covered by JTWC's AOR and provide forecast positions at 24-, 48-, and 72-hours unless the technique aborts prematurely during computations. The techniques can be divided into six general categories: extrapolation, climatology and analogs, statistical, dynamic, hybrids, and empirical or analytical.

5.2.1 EXTRAPOLATION (XTRP) — Past speed and direction are computed using the rhumb line distance between the current and 12-hour old positions of the tropical cyclone. Extrapolation from the current warning position is used to compute forecast positions.

5.2.2 CLIMATOLOGY and ANALOGS

5.2.2.1 CLIMATOLOGY (CLIM) — Employs time and location windows relative to the current position of the storm to determine which historical storms will be used to compute the forecast. The historical data base is 1945-1981 for the Northwest Pacific, and 1900 to 1990 for the rest of JTWC's AOR. A second climatology-based technique exists on JTWC's Macintosh®™ II computers. It employs data bases from 1945 to 1992 and from 1970 to 1992. The latter is referred to as the satellite-era data base. Objective intensity forecasts are available from these data bases. Scatter diagrams of expected tropical cyclone motion at bifurcation points are also available from these data bases.

5.2.2.2 ANALOGS — JTWC's analog and climatology techniques use the same historical data base, except that the analog approach imposes more restrictions on which storms will be used to compute the forecast positions. Analogs in all basins must satisfy time, location, speed, and direction windows, although the window definitions are distinctly different in the Northwest Pacific. In this basin, acceptable analogs are also ranked in terms of a similarity index that includes the above parameters and: storm size and size change, intensity and intensity change, and heights and locations of the 700-mb subtropical ridge and upstream midlatitude trough. In other basins, all acceptable analogs receive equal weighting and a persistence bias is explicitly added to the forecast. Inside the Northwest Pacific, analog weighting is varied using the similarity index, and a persistence bias is implicitly incorporated by rotating the analog tracks so that they initially match the 12-hr old motion of the current storm. In the Northwest Pacific, a forecast based on all acceptable analogs called TOTL, as well as a forecast based only on historical recurvers called RECR are available. Outside this basin, only the TOTL technique is available.

5.2.3 STATISTICAL

5.2.3.1 CLIMATOLOGY AND PERSISTENCE (CLIP) — A statistical regression technique that is based on climatology, current position and 12-hour and 24-hour past movement. This technique is used as a crude baseline against which to measure the forecast skill of other more sophisticated techniques. CLIP in the Northwest Pacific uses third-order regression equations and is based on the work of Xu and Neumann (1985). CLIP has been available outside this basin since mid-1990, with regression coefficients recently recomputed by FNOC based on the updated 1900-1989 data base.

5.2.3.2 COLORADO STATE UNIVERSITY MODEL (CSUM) — A statistical-dynamical technique based on the work of Matsumoto (1984). Predictor parameters include the current and 24-hr old position of the storm, heights from the current and 24-hr old NOGAPS 500-mb analyses, and heights from the 24-hr and 48-hr NOGAPS 500 mb prognoses. Height values from 200-mb fields are substituted for storms that have an intensity exceeding 90 knots and are located north of the subtropical ridge. Three distinct sets of regression equations are used depending on whether the storm's direction of motion falls into "below," "on," or "above" the subtropical ridge categories. During the development of the regression equation coefficients for CSUM, the so-called "perfect prog" approach was used, in which verifying analyses were substituted for the numerical prognoses that are used when CSUM is run operationally. Thus, CSUM was not "tuned" to any particular version of NOGAPS, and in fact, the performance of CSUM should presumably improve as new versions of NOGAPS improve. CSUM runs only in the Northwest Pacific, South China Sea, and North Indian Ocean basins.

5.2.3.3 JTWC92 (JT92) - JTWC92 is a statistical-dynamical model for the Northwest Pacific Ocean basin which forecasts tropical cyclone positions at 12-hour intervals to 72 hours. The model uses the deep-layer mean height field derived from the NOGAPS forecast fields. These deep-layer mean height fields are spectrally truncated to wave numbers 0 through 18 prior to use in JT92. Separate forecasts are made for each position. That is, the forecast 24 hour position is not a 12-hour forecast from the forecasted 12-hour position.

JT92 uses five internal sub-models which are blended and iterated to produce the final forecasts. The first sub-model is a statistical blend of climatology and persistence, known as CLIPER. The second sub-model is an analysis mode predictor, which only uses the "analysis" field. The third sub-model is the forecast mode predictor, which uses only the forecast fields. The fourth sub-model is a combination of 1 and 2 to produce a "first guess" of the 12-hourly forecast positions. The fifth sub-model uses the output of the "first guess" combined with 1,2, and 3 to produce the forecasts. The iteration is accomplished by using the output of sub-model 5 as though it were the output from sub-model 4. The optimum number of iterations has been determined to be three.

When JT92 is used in the operational mode, all the NOGAPS fields are forecast fields. The 00Z and 12Z tropical forecasts are based upon the previous 12-hour old synoptic time NOGAPS forecasts. The 06Z and 18Z tropical forecasts are based on the previous 00Z and 12Z NOGAPS forecasts, respectively. Therefore, the second sub-model uses forecast fields and not analysis fields operationally.

5.2.4 DYNAMIC

5.2.4.1 NOGAPS VORTEX TRACKING ROUTINE (NGPS) — This objective technique follows the movement of the point of minimum height on the 1000 mb pressure surface analyzed and predicted by NOGAPS. A search in the expected vicinity of the storm is conducted every six hours through 72 hours, even if the tracking routine temporarily fails to discern a minimum height point. Explicit insertion of a tropical cyclone bogus via data provided over TYMNET by JTWC began in mid-1990, and should improve the ability of the NOGAPS technique to track the vortex.

5.2.4.2 ONE-WAY INFLUENCE TROPICAL CYCLONE MODEL (OTCM) — This technique is a coarse resolution (205 km grid), three layer, primitive equation model with a horizontal domain of 6400 x 4700 km. OTCM is initialized using 6-hour or 12-hour prognostic fields from the latest NOGAPS run, and the initial fields are smoothed and adjusted in the vicinity of the storm to induce a persistence bias into OTCM's forecast. A symmetric bogus vortex is then inserted, and the boundaries updated every 12 hours by NOGAPS fields as the integration proceeds. The bogus vortex is maintained against frictional dissipation by an analytical heating function. The forecast positions are based on the movement of the vortex in the lowest layer of the model (effectively 850-mb).

5.2.4.3 FNOC BETA AND ADVECTION MODEL (FBAM) — This model is an adaptation of the Beta and Advection model used by NMC. The forecast motion results from a calculation of environmental steering and an empirical correction for the observed vector difference between that steering and the 12-hour old storm motion. The steering is computed from the NOGAPS Deep Layer Mean (DLM) wind fields which are a weighted average of the wind fields computed for the 1000-mb to 100-mb levels. The difference between past storm motion and the DLM steering is treated as if the storm were a Rossby wave with an "effective radius" propagating in response to the horizontal gradient of the coriolis parameter, Beta. The forecast proceeds in one-hour steps, recomputing the effective radius as Beta changes with storm latitude, and blending in a persistence bias for the first 12 hours.

5.2.5 HYBRIDS

5.2.5.1 HALF PERSISTENCE AND CLIMATOLOGY (HPAC) — Forecast positions are generated by equally weighting the forecasts given by XTRP and CLIM.

5.2.5.2 COMBINED CONFIDENCE WEIGHTED FORECASTS (CCWF) — An optimal blend of objective techniques produced by the ATCF. The ATCF blends the selected techniques (currently OTCM, CSUM and HPAC) by using the inverse of the covariance matrices computed from historical and real-time cross-track and along-track errors as the weighting function.

5.2.6 EMPIRICAL OR ANALYTICAL

5.2.6.1 DVORAK — An estimation of a tropical cyclone's current and 24-hour forecast intensity is made from the interpretation of satellite imagery (Dvorak, 1984) . These intensity estimates are used with other intensity related data and trends to forecast short-term tropical cyclone intensity.

5.2.6.2 MARTIN/HOLLAND — The technique adapts an earlier work (Holland, 1980) and specifically addresses the need for realistic 30-, 50- and 100-kt (15-,26- and 51-m/sec) wind radii around tropical cyclones. It solves equations for basic gradient wind relations within the tropical cyclone area, using input parameters obtained from enhanced infrared satellite imagery. The diagnosis also includes an asymmetric area of winds caused by tropical cyclone movement. Satellite-derived size and intensity parameters are also used to diagnose internal steering components of tropical cyclone motion known collectively as "beta-drift".

5.2.6.3 TYPHOON ACCELERATION PREDICTION TECHNIQUE (TAPT) — This technique (Weir, 1982) utilizes upper-tropospheric and surface wind fields to estimate acceleration associated with the tropical cyclone's interaction with the mid-latitude westerlies. It includes guidelines for the duration of acceleration, upper limits and probable path of the cyclone.

5.3 TESTING AND RESULTS

A comparison of selected techniques is included in Table 5-5 for all Northwest Pacific tropical cyclones; Table 5-6 for all North Indian Ocean tropical cyclones and Table 5-7 for the Southern Hemisphere. In these tables, "x-axis" refers to techniques listed vertically. For example (Table 5-5) in the 861 cases available for a (homogeneous) comparison, the average forecast error at 24 hours was 137 nm (254 km) for CSUM and 139 nm (257 km) for FBAM. The difference of 2 nm (4 km) is shown in the lower right. (Differences are not always exact, due to computational round-off which occurs for each of the cases available for comparison).

TABLE 5-5

1992 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTHWEST PACIFIC (1 JAN 1992 - 31 DEC 1992)

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		CLIP		HPAC	
JTWC	841	107												
	107	0												
NGPS	427	99	428	146										
	146	47	146	0										
OTCM	795	105	421	145	881	129								
	126	21	117	-28	129	0								
CSUM	793	107	419	144	846	127	872	146						
	129	22	121	-23	145	18	146	0						
FBAM	804	107	416	145	866	128	861	137	891	140				
	138	31	138	-7	140	12	139	2	140	0				
CLIP	814	107	422	146	876	128	868	137	888	140	905	140		
	134	27	121	-25	139	11	133	-4	140	0	140	0		
HPAC	809	107	422	145	862	128	866	137	874	139	887	135	888	139
	136	29	126	-19	136	8	139	2	139	0	139	4	139	0

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		CLIP		HPAC	
JTWC	685	205												
	205	0												
NGPS	360	201	364	238										
	237	36	238	0										
OTCM	641	202	356	233	756	229								
	226	24	219	-14	229	0								
CSUM	651	204	355	234	723	228	755	252						
	235	31	236	2	251	23	252	0						
FBAM	658	204	353	235	743	228	745	241	775	257				
	253	49	258	23	256	28	255	14	257	0				
CLIP	665	204	358	237	751	229	751	242	772	257	788	277		
	261	57	246	9	276	47	262	20	277	20	277	0		
HPAC	661	204	358	236	739	229	750	242	759	256	771	264	772	255
	247	43	247	11	253	24	256	14	255	-1	256	-8	255	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		NGPS		OTCM		CSUM		FBAM		CLIP		HPAC	
JTWC	565	305												
	305	0												
NGPS	271	297	280	319										
	313	16	319	0										
OTCM	521	300	265	315	629	326								
	326	26	314	-1	326	0								
CSUM	544	302	273	313	601	327	645	340						
	330	28	338	25	332	5	340	0						
FBAM	549	303	274	316	619	325	638	339	664	373				
	363	60	364	48	367	42	369	30	373	0				
CLIP	553	303	276	319	626	326	642	340	661	374	675	402		
	386	83	374	55	392	66	385	45	400	26	402	0		
HPAC	548	302	276	318	612	326	638	340	645	370	655	387	656	355
	348	46	343	25	349	23	356	16	354	-16	355	-32	355	0

JTWC - JTWC Forecast
NGPS - Navy-Operational Global-Atmospheric Prediction System
OTCM - One-Way Tropical Cyclone Model
CSUM - Colorado State University Model
FBAM - FNOC Beta and Advection Model
CLIP - Climatology/Persistence
HPAC - Half Persistence and Climatology

TABLE 5-6

1992 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE NORTH INDIAN OCEAN (1 JAN 1992 - 31 DEC 1992)

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		FBAM		CLIP		HPAC		TOTL		CLIM	
JTWC	147	128												
	128	0												
OTCM	140	128	155	146										
	141	13	146	0										
FBAM	141	129	155	146	156	144								
	144	15	145	-1	144	0								
CLIP	141	129	155	146	156	144	156	146						
	141	12	146	0	146	2	146	0						
HPAC	141	129	155	146	156	144	156	146	156	148				
	145	16	148	2	148	4	148	2	148	0				
TOTL	126	133	135	147	136	146	136	146	136	152	136	153		
	152	19	153	6	153	7	153	7	153	1	153	0		
CLIM	141	129	155	146	156	144	156	146	156	148	136	153	156	157
	157	28	158	12	157	13	157	11	157	9	164	11	157	0

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		FBAM		CLIP		HPAC		TOTL		CLIM	
JTWC	99	245												
	245	0												
OTCM	82	240	95	277										
	275	35	277	0										
FBAM	95	247	95	277	111	256								
	267	20	259	-18	256	0								
CLIP	95	247	95	277	111	256	111	259						
	268	21	254	-23	259	3	259	0						
HPAC	94	247	94	279	110	257	110	260	110	262				
	271	24	258	-21	262	5	262	2	262	0				
TOTL	76	254	69	287	85	258	85	253	85	256	85	276		
	284	30	267	-20	276	18	276	23	276	20	276	0		
CLIM	94	247	94	279	110	257	110	260	110	262	85	276	110	262
	280	33	265	-14	262	5	262	2	262	0	260	-16	262	0

72-HOUR MEAN FORECAST ERROR (NM)

	JTWC		OTCM		FBAM		CLIP		HPAC		TOTL		CLIM	
JTWC	61	402												
	402	0												
OTCM	42	386	56	486										
	499	113	486	0										
FBAM	58	406	56	486	75	408								
	423	17	394	-92	408	0								
CLIP	58	406	56	486	75	408	75	404						
	423	17	387	-99	404	-4	404	0						
HPAC	58	406	56	486	75	408	75	404	75	398				
	409	3	361	-125	398	-10	398	-6	398	0				
TOTL	44	428	38	501	52	432	52	387	52	390	52	435		
	449	21	383	-118	435	3	435	48	435	45	435	0		
CLIM	58	406	56	486	75	408	75	404	75	398	52	435	75	342
	371	-35	317	-169	342	-66	342	-62	342	-56	353	-82	342	0

JTWC - JTWC Forecast
OTCM - One-Way Tropical Cyclone Model
FBAM - FNOC Beta and Advection Model
CLIP - Climatology/Persistence
HPAC - Half Persistence and Climatology
TOTL - Total Analog
CLIM - Climatology

TABLE 5-7

1992 ERROR STATISTICS FOR SELECTED OBJECTIVE TECHNIQUES IN THE SOUTHERN HEMISHERE (1 JUL 1991 - 30 JUN 1992)

24-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	TOTL	CLIM	XTRP
JTWC	234 125							
	125 0							
OTCM	213 117	368 133						
	123 6	133 0						
FBAM	210 123	350 134	357 181					
	179 56	178 44	181 0					
CLIP	219 124	365 132	355 180	373 169				
	166 42	167 35	171 -9	169 0				
HPAC	219 124	365 132	355 180	373 169	373 150			
	144 20	148 16	152 -28	150 -19	150 0			
TOTL	117 125	175 125	175 184	182 160	182 139	182 141		
	150 25	134 9	138 -46	141 -19	141 2	141 0		
CLIM	219 124	367 132	356 180	373 169	373 150	182 141	375 197	
	187 63	195 63	198 18	196 27	196 46	179 38	197 0	
XTRP	219 124	366 132	356 180	373 169	373 150	182 141	374 196	374 151
	146 22	147 15	152 -28	151 -18	151 1	141 0	151 -45	151 0

Number of Cases	X-Axis Technique Error
Y-Axis Technique Error	Error Difference (Y-X)

48-HOUR MEAN FORECAST ERROR (NM)

	JTWC	OTCM	FBAM	CLIP	HPAC	TOTL	CLIM	XTRP
JTWC	184 242							
	242 0							
OTCM	165 238	307 243						
	236 -2	243 0						
FBAM	168 242	290 243	304 315					
	306 64	317 74	315 0					
CLIP	175 240	305 243	303 316	320 283				
	285 45	280 37	288 -28	283 0				
HPAC	175 240	305 243	303 316	320 283	320 256			
	246 6	254 11	260 -56	256 -27	256 0			
TOTL	88 229	135 224	137 304	143 260	143 232	143 259		
	265 36	257 33	258 -46	259 -1	259 27	259 0		
CLIM	175 240	307 243	304 315	320 283	320 256	143 259	322 335	
	322 82	328 85	339 24	333 50	333 77	301 42	335 0	
XTRP	175 240	306 243	304 315	320 283	320 256	143 259	321 334	321 285
	276 36	284 41	287 -28	285 2	285 29	264 5	285 -49	285 0

JTWC - JTWC Forecast
CLIP - Climatology/Persistence
TOTL - Total Analog
XTRP - Extrapolation
OTCM - One-Way Tropical Cyclone Model
HPAC - Half Persistence and Climatology
CLIM - Climatology

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